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Telecommunication Media: A detail comparison and future perspectives

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ABSTRACT

Like every other engineering field, telecommunication is a constantly and quickly developing field of technology. Thanks to the latest economical innovations in research which have made costly equipment easily accessible and paved a path for their abundance use on commercial basis. Here, in this article, we are going through a detail overview of all those innovations made in telecom industry from the last two centuries to present day. We will compare all available media of communication i.e. from copper wire to Fiber optics and from Morse code to Satellite Communication etc, and in the end we will also try a prediction of winning technology. So gear-up and let's start.

Keywords - **channels, comparison, copper wire, co-axial cable, Fiber Optics, merits-demerits, prognostication, Wireless communication.**

1. Introduction

This was in history a time, which no one knows the exact date of, when communication was purely in physical form: smoke signals, fire signals, and runners in between the sender and receiver. Though, all these ways were fulfilling the need which was *to communicate*, the process was sluggish. One needed to wait for days or even months for 'Breaking News' to arrive. Sometimes this news arrival could break up altogether when factors like weather and war would come in between the communicators. Necessity is the mother of invention, in 19th Century human kind invented wired communication systems when Graham bell came up with the patent of copper wire telephony in 1876 [1]. Not long after - just twelve years, Heinrich Hertz in 1888 came forward with the theory of Electromagnetism which smoothen a path for wireless communication. In the very same year Thomas Edison confirmed that information transmission through Electromagnetic waves is possible. Guglielmo Marconi successfully sent first long distance wireless message across English Channel and the year was 1895 [2]. And it all started up!

Now, we are having two possibilities in order to communicate – Wireless and Wired Telecommunication. Let's look into the wired communication first.

2. Communication Channels

2.1 Wired Communication

2.1.1 Copper Wire

Communication signal, in its primary form, is energy signal like electricity and for that copper is the best

medium. It is a good conductor; can pass through electrical power with very meager loses. It is economical and easy to install, requires no or very little expertise. Safety precautions are few and easy to manipulate, no special equipment are required. But there are factors which make it less attractive for long haul communication. Copper loses its conductive nature with time results more and more attenuation (internal signal loss due to impurities and/or change of material properties). It is also very vulnerable to stray Electromagnetic fields (EM) present in the atmosphere every time everywhere, as it acts like a simple two wire antenna and can easily pick-up energy from environment ultimately producing interference with useful data and sometimes a complete loss is inevitable. The data security is almost zero. By just peeling off insulation and connecting another copper wire makes it all. By this way anyone can retrieve each and every bit of information traveling through the medium.

2.1.2 Co-axial Cables

Some shortcomings of Copper wire were overcome by the coaxial cable. It is not a new technology either but very efficient and still in use by landline and Mobile Companies as a communication channel. It is sophisticated and cheap, composed of a traditional copper wire with a hard plastic coating and another wire around it in the form of a braid. The information goes through centre copper wire while outer braiding provides a shield from the EM waves. The braiding is useful in a sense that it grounds all unwanted signals and prevent useful information from being degraded or lost. Plastic shielding separates internal wire from the braiding and the whole assembly is secured in a coating jacket. Information security is still an issue here, but it can be compromised on considering other benefits of these cables, like low cost and efficiency. The Coaxial cables are so useful and practically shows no shortcoming until we speak of high frequencies. When frequency reaches 1GHz, the point where range of frequencies called microwaves starts, losses in coaxial cable appear prominent. The phenomenon is known as skin effect. By definition*, it is a loss of useful energy which occurs when carrying conductor is no more capable of containing information energy in its physical dimension*. Frequency above 1 GHz tends to show up at the very skin of conductor leaving its center rather completely empty, with no energy signal. The fact behind is that: the coaxial conductor behaves like an antenna, it tries to spread energy into the air thus losses occur. But we need to send signals of frequency greater than 1GHz in order to obtain greater bandwidth for an enormous information transmission. So, we have to look for more improvement and are compelled to switch to Waveguides or Fiber Optics transmission lines.

2.1.3 Waveguides

Waveguides are hollow rectangular or circular pipes (former are more common) which are precisely engineered keeping an exact ratio of physical dimension with the energy signal's frequency for proper communication. This ratio demands that waveguide's width should be one-half of the lowest operating frequency called cutoff frequency (lowest frequency in operational frequency range) (w=1/2 * fco) and height should be one-half of the width of waveguide (h=1/2 * w). Waveguide function is very simple, you need a copper wire at the start of it to inject microwave signal into the cavity; such will behave like an antenna, and on the other end same can be retrieved by an identical conductor. These conductors are called probes. Generated energy will propagate forward by continuously reflecting from inner walls of waveguide. A frequency equal to or lower than cutoff frequency fails to propagate as it won't have any incident angle at the stage of leaving the probe; as a result wave will bounce back and forth at one specific point [3]. One can imagine how crucial dimensions can be in Telecom equipment for communication to be successful. Waveguides are efficient in use and economical, but they are

commonly used as a short distant medium; from transmitter module to antenna or vice versa or in PCB circuitry in the form of striplines and microstrips. Their use for long distance communication is practically improbable because their losses will be huge if a dimensional flaw occurs, and of course, hollow pipes are more fragile than solid copper bundles.

Before going into the details of wired communication giant, so called Fiber Optics, let's look into Wireless World first as in frequency spectrum microwave frequencies come first before visible spectrum.

2.2 Wireless Communication

2.1.1 Radio & microwaves Communication

Communication wirelessly is a very useful innovation and great success of science. This technology modernized and became popular very quickly because it made practical so many impossibilities. By wireless communication we have accessed there where human can't intrude physically. We can communicate with very few equipment and can trace every patch and swath of this land (GPS). Its use made every single person in easy access (GSM). These are among many examples set by Wireless Comm.

In fact, the 1GHz frequency is not the starting point to wireless world; it is possible in even much lower frequencies as well. Human voice frequency range is from 20 Hz to 20 kHz and it is wireless already. Low frequency signals, as we know, are lower energy signals. They cannot travel longer distances without being affected by atmospheric hindrances like moisture, dust, physical blockage in the form of wall or rocks, and even the direction of air is enough to degrade them. The AM (Amplitude Modulated) and FM(Frequency Modulated) channels are voice frequencies modulated or enhanced with higher frequencies in order to provide them enough energy to cover more distance with less attenuation and losses.

But, from 1GHz the real story begins. You cannot just send signals of such frequency in the air hoping that your receiver will catch them, because if you do that you won't be successful. Here, in this range, starts Line Of Sight (LOS) communication. For LOS Wireless communication to take place the transmitter antenna, which is usually manufactured in the form of a dish, must be very aligned with the receiver antenna or dish, moreover no obstacle should come in between the two. Microwave travels in straight line, it won't bend with the curvature of earth or over surfaces, mountains or buildings, like AM wave does, but totally absorbed. The strange thing is; they don't get absorbed by ionosphere where this property switches to AM signals. So, by using Microwave, we can send our messages to other planets or to make Satellites Communication possible. Scientists and Astronauts extensively use microwave in communicating with heavenly bodies and in finding out the concealed mysteries which are spread across our planet and beyond.

We, presently, are using microwaves both on land and in satellites and both are for communication purposes (considering every signal interchange as communication signaling regardless of their use and purpose). On land, we have covered a good percentage of earth's crest with GSM mobile communication signals, as it implies Global System for Mobile Communication (GSM). Its services are available in nearly every country with different brand names but with the same standards, rules and frequencies. GSM works in two bands of frequencies – 900MHz and 1800MHz (0.9GHz and 1.8GHz), later is a modified form known as DCS (Digital Cellular Service) where we have advantage of higher bandwidth i.e. a channel of 75MHz as compare to 25 MHz channel of typical GSM, all other services and standards are same. There are two simultaneous

actions which are taking place within a GSM Station or Base Transceiver Station (BTS) at a given time; a user to mobile tower link and a mobile tower to another mobile tower link. First link is usually called a Radio Link and later is called a Microwave Link. Here, as we know, line of sight is critical between Microwave links in order to facilitate users with a good connectivity everywhere. We can see many dish antennas attached with mobile towers for such purpose. For radio communication i.e. from user to tower or vice versa, we have horizontal antennas tied-up with the tower. They might be Omni directional or angular depending on the situation and requirements. Uplink and downlink frequencies are kept differ in each every case (GSM and DCS) as a preventive measure against channels mixing. Frequency reuse is very common in Mobile Communication after every 2, 4, or 7 adjacent cells. This helps in doubling the bandwidth, while having a limited frequency band. GSM Mobile communication is also called Cellular Communication, because its tower coverage is considered a shape of honeycomb, which in fact is just for theoretical convenience only.

As we know, in order to increase information flow and to maximize the efficiency of a channel a technique called Multiplexing is used - a medium carries multiple signals coded in terms of frequency or time but sustain their individual identity for intended receivers without mixing up in reality. GSM uses Time Division Multiplexing (TDM) for Users data transmission. The Voice signal is digitized by an A/D converter and further into serial format. The serial voice data is than Time multiplexed into eight channels which may contain data if in use or go blank if not in use.

Mobile communication is developing very rapidly and so far very successful. Companies are providing more and more value added services with GSM and they are great. By just looking around one can see that a mobile phone is now a common gadget like a pen. Based on its success and services, this can be said that it will prevail and develop to the most sophisticated level. Of course, No wire technology can compete the GSM wireless communication in terms of mobility, and services on the go. Though it is available not everywhere, but spreading quickly. With GSM, other services of Microwaves are Wi-Fi, Bluetooth, and Infra Red bridges. These are packet data services for internet and data communication and are not intended for voice calls in general.

For users, GSM is wireless, where in reality it is wireless but to some extent. From a User station, usually a handset, to the BTS tower the communication is done by microwaves but the bulk of accumulated calls and packet data streams of GPRS from active users present at that time in that specific cell couldn't be handled wirelessly and there comes Fiber Optics to play its role. Within an area amongst many, one or two sites are connected with Fiber optics which is called Up-Sites. Up-sites take data from all other towers and send them to BSC (Base Switching Centre) and further to MSC (Main Switching Centre). But again, this is not always a thumb rule; for some very remote stations we may not be able to connect via any cable economically. There we got only one solution – Satellite Communication.

2.1.2 Satellite Communication

Communication via satellite is like a day dreaming. Throwing signal from one point on the earth crest towards open sky and there some heavenly object catches it, modify it in some order to make it better, and send it back to another point on the earth crest which is possibly laying a thousand of Kilometers from the first point, all seems a magic spell. But we know this is happening every day, every second. Satellites are used, broadly in a sense, for communication purpose. They offer a wide bandwidth in addition to large coverage area. Hundreds and Thousands of Voice calls, TV Channels,

GPS Signals, and exploratory signals are interchanged from earth with satellites and back. The curvature of earth is a prominent factor in microwave communication and repeaters are required to convey energy signals after specific distances depending upon the antenna height, so they may not get absorbed by earth. Communication Satellites are repeater not on the earth but in the sky.

Satellites are divided in three categories based on their distance from the earth: Geostationary Earth Orbit (GEO), Medium Earth Orbit (MEO), and Low Earth Orbit (LEO). The first ones- GEO, are satellites having a distance of nearly 35,786 KM from the Earth and right on equator. The distance plays a vital role here, for a satellite or any other object in order to be synchronous with Earth's movement has to be far a distance of this specific value from the Earth. So, these satellites spot a specific area of Earth and not losing their viewing zone with time, appears relatively stationary. The main purpose of satellite in this orbit is Television Transmission, Weather forecasting, and Communication. When used for Communication it comes with three discrepancies: first, it creates a time delay or latency of approximately 250 ms in voice calls in one cycle (from earth station to satellite and back: Uplink and Downlink) due to its great distance from earth. Second, its coverage degrades when we move from equator towards poles. The third one is alignment; an antenna/dish must be very aligned with the satellite or otherwise no communication will take place. Still, this orbit is unique and valuable, so is the reason that International Telecommunication Union (ITU) has assigned specific location and frequencies to countries wishing a satellite in GEO. MEO Satellites are the second farthest from the earth. Its distance is rather a range than a specific value which starts from 2000 Km to 35000 Km. There are many satellites in this orbit for different purposes but GPS (Global Positioning System/Satellites) which are at least 24 in number, are well known and satellites which make communication possible on South and North poles are also laying in this orbit. They promise a better communication as compare to GEO when we speak of time delay, and also, they are having a good footprint on earth with respect to LEO, yet cost is a universal issue associated with satellites. LEO satellites are used for communication purpose and surveillance. These are located somewhere between 1200 Km to 2000 Km. According to law of physics, an object nearer to Earth will move faster if provided with necessary initial velocity which implies that LEO are the fastest moving satellites, some of which can cover its rotation in 90 minutes only. Two networks of satellite are currently active for communication purpose in this orbit: Iridium with 66 satellites and Globalstar with 48 satellites. A constellation of satellites is necessary for proper communication to take place in LEO based communication system as we know that these satellites are constantly moving and coverage is an issue if numbers are few. The advantage of this orbit is the highest voice quality, ever possible from satellites, as compare to GEO and MEO, because of their short distance and advantage of not needing many amplifiers. Even a low power handset can catch signal with clarity and efficiency. Iridium constellation is very effective in a sense that they have made communication on poles possible as they are capable to communicate with one another or inter-satellite communication. Some weaknesses of satellites in LEO are; Doppler effect due to relative velocity, cost of constellation satellites, and atmospheric effect which can deviate it from the allocated path.

Frequencies which are useful in satellite communication are Microwave frequencies, further divided into sub-categories. Mostly in use are L, S, C, X, Ku, K, and Ka. Mobile Services Satellites (MSS) are using L and S bands, comprising a frequency range from 1 to 4 GHz, most of the cases. While in general,

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for communication, satellites are set on C band which has a range from 4 GHz to 8 GHz, but this spectrum is overcrowded already and many new satellites are shifting to K band rather than C band. We have some techniques to avoid the bandwidth bottlenecking such as Frequency reuse by means of polarization and Spatial Isolation by using narrow beam antennas.

2.1.3 DEMERITS OF WIRELESS COMMUNICATION

With so much in the credit of Wireless Communication let's have a look at their weak points as well. Like Copper and Co-axial cable, Wireless communication is not secured. While so many security suits and protocols are being developed for such purpose still it is easy to cheat. Mix channeling and frequency sharing is another problem, where two users accidently came across using same frequency for communication. Wireless Communication requires great planning and precision. It also has affects on the human health when frequency pollution occurs in an area. ITU&T and IEEE have implemented set regulations to limit frequency crowding in an area. The wireless signals are Energies which may cause harm, even cancer, in human body if exposed for a very long time [4]. WHO has categorized Microwave signal in Group-2B, which means there could be some risk [5]. It has the biggest problem of Bandwidth Bottleneck. Bandwidth is the difference of Highest and Lowest frequency in a communication channels. Higher Bandwidth means more room for information to be carried. An important point is, when we go from lower to higher in terms of frequency in the frequency spectrum we get greater bandwidth in result. As, if we are communicating in FM, we have bandwidth in Mega Bits (Mbs), and if we are communicating in Microwave, our bandwidth limit will be in Giga Bits (Gbs). The bandwidth issue is also related to satellite communication. A satellite can interchange set number of channels and there is no alternative if number exceeds.

One might say, what is the big deal here; we must go to higher frequencies if we want? Aren't we? The answer is NO we can't, as, this would be against regulations because higher frequencies will contain greater energies and thus more harmful for human body and they will have a tendency of deterioration. In addition, equipments will get more and more complex and with complexity comes cost issue.

2.3 COMMUNICATION USING LIGHT WAVE

2.3.1 NTRODUCTION

Next to Microwave is Light in The Frequency Spectrum. Light is visible to the human eye. It travels 186,282 kilometer per second. Communication using light is not new at all; our ancestors used light, in the form of fire, to signal each other of any peril coming ahead. The Light has very high frequency (405 -790 Tera Hertz (THz)) which justifies that it can compensate, ideally, infinite data- very wide bandwidth. It can be transmitted wirelessly or with a special type of wire called Fiber Optics. When transmitted wirelessly, it can cover a distance of million miles (we can see the stars), but will loss permanently if some opaque object comes in between the transmission path way such as clouds, fog, dust, solid object or if LOS get misaligned.

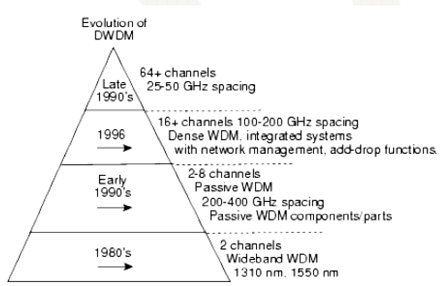
2.3.2 FIBER OPTICS COMMUNICATION

We use fiber optics to get rid of these problems. Fiber Optics is a hollow glass wire made of pure Silica or plastic. It acts like a crystal bridge for light, like iron pipe for water or waveguide for Microwaves. The fiber optics communication is very reliable with ideally zero loss, negligible attenuation, high speed, and data security. The possibility of EM interference from the environment is very less. Optical Networking is already deployed extensively in developed countries while in other it is present in primitive form but expending quickly in order to cope with high bandwidth requirements. At First, it was only used as Trans-Oceanic communication

gateway medium which connects one continent from other and for voice calls only, but with research and more effective ways of economical manufacturing it has made access to Telecom Exchanges and further to User Cabinets called Optical Network Units (ONUs). Due to its wide bandwidth, many wireless telecom companies are using it for their Up-Sites data and calls transmission as we have discussed before. Their use promises all in one possibility according to which only one line will provide high speed internet, HD TV, and video and voice Telephony.

The multiplexing technique is also applicable in Fiber Optics where light frequencies are separated by their unique wavelengths (or simply color if system is based on light source rather than Lasers) so called Wavelength Division Multiplexing (WDM). Its modern form is Dense Wavelength Division Multiplexing (DWDM) for they can carry up to 160 Parallel Channels separated by 50 or even 25 GHz narrow intervals [6]. The pyramid in fig. shows the chronicle development of DWDM in terms of an increase in their number of channels – Only 2 in 1980's and 64-160 in late 1990's.

In few years, the number of channels will grow manifold and fiber optics will be able to carry a gigantic volume of data, so we could call it an infinite bandwidth. Now, Scientists are exploring another use



Evaluation of DWDM – from 1980 to 2000

Of fiber optics which is an aim to pass electric power through Fiber optics. Though, it is done already on small scale but for commercial use is still under research phase [7]. If successful, this will revolutionize our world.

Nothing is ideal. Fiber optics has its constraints as well. First of all, it is still expensive and requires special equipments for deployment and quite trained personnel. The associated material like Lasers, Multiplexers, Combiners and amplifiers are also come under costly material. The safety issue also persists, as glass fiber is very sharp which can cut easily and eyes should be protected by safety goggles as Lasers are usually used in Fiber Optics Transmission. Secondly, it allows a factor of degradation in communicating signal if material of fiber optics is not so pure, which implies the fact that light is easily absorbable. Though enforced with Kevlar fibers for strength, still fiber optic is fragile in bending angle; which may affect its performance right away or with time so care must be taken. One of born-up-with issue of fiber optics communication is scattering. It occurs due to irregular surface of silica or plastic which can be great enough to disorient a light wave completely. Scattering depends on wavelength, which in the case of light is very short (in Angstroms) thus a small irregularity can be a great deal.

3. Conclusion

Now, let's take a comparison of all these available mediums of Telecommunication and decide which to vote for.

First, beside all its frailties, copper wire is not going to obsolete from the communication world due to its low manufacturing cost. It will vanish only when the entire network and their components would manufacture using Optical Fibers. Second, the co-axial cables are as effective today as they were before. It also faces the danger of ALL FIBER

terminology, and we know that it will take time. Third is the wireless Communication. The main rivals are Wireless and Fiber Optics on this ground, but instead of one knocking out the other from the competition ring, they will support each other. The optical fiber will overcome the bandwidth and health & data safety issue of wireless and wireless technology will continue providing communication mobility and independence. And of course, when one talks about satellite communication and constantly moving bodies like aero-planes where we can't hookup wires! We will be using Wireless Communication. If quantum computers and modern photonics equipment get introduced, they will surely appeal for medium of light then electrons. Future is surely of Fiber Optics and sophisticated Wireless Systems. It is very confirmed that one technology cannot totally obsolete the other because their individual services are incomparable. Wire and Wireless goes hand in hand as they were for the last two centuries, though their greatly modified forms indeed.

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